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THE CALIFORNIA GRAPE ROOT-WORM.

By H. J. QUAYLE.

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THE CALIFORNIA GRAPE ROOT-WORM.

(*Adoxus obscurus* Linn.)

By H. J. QUAYLE.

The California Grape Root-worm is an insect that attacks both the roots and the growing parts of the vine above ground. It has been known to attack the leaves of the vine in this State for a good many years, but until a year or two ago it was unknown as a root feeder. It is similar in its life history and mode of attack to the well-known grape root-worm of the Eastern States, which is one of the worst pests that the vineyardists there have to wage war against. Our species has been doing considerable damage during the past two or three years, and it promises to be an important enemy of the vine in California.

Early History in Europe.—The first account of this insect, which leaves little doubt as to its identity, was given by Aldrovandi in 1602.[1] It is one of the important pests of the vine in France, as is shown by the amount of literature on the insect that has appeared in that country. Pluchi[2] in 1732 stated that it passed the winter in the ground, and this is the first suggestion we have of its underground habits, although it was not actually known by this author to feed upon the roots. The first authentic observation on the root-feeding habits appears to have been made in 1849 by Demermety,[3] who found it feeding upon the roots of vines in France.

It has received rather careful attention from a number of observers in Europe, but probably the most complete account is given in Mayet's "Insectes de la Vigne." It also occurs, as a grape pest, in Germany, Italy, and Algeria, as well as in France.

In California.—The first account of this insect occurring on vines in California, so far as we have been able to find, is a brief notice in the "Pacific Rural Press" for May 29, 1880. It is here stated that "every spring for the last few years there have been received specimens of a dark colored beetle about one fifth of an inch long which eats the leaves of the grapevine until almost skeletonized." It is doubtful from this account just what beetle is referred to, but the description of the beetle and its work on the leaves, and the time of the year of its occurrence,

[1] Des Insectes, p. 472.

[2] Spectacle de la Nature; Paris.

[3] Jour. d'Agr. de Dijon.

suggests the root beetle. Moreover, Professor Wickson who was horticultural editor of the "Press" at the time, remembers that the article had reference to this species as we now know it, and not to the flea-beetle with which it has been commonly confused.

The first full account of its occurrence in this State appears in an article by Matthew Cooke[1] in 1883. He confuses it with the flea-beetle, but he gives it the scientific name of *Adoxus vitis,* and from his account there is no mistaking the insect to which he refers. He states that "it was reported from at least six of the vine-growing sections of the State in 1882, and in 1883 was destroying the vines infested. One vineyard in the vicinity of Sacramento was damaged seriously that spring. Its mode of attack is similar to that of the steel-blue flea-beetle (*Haltica chalybea* Ill.), and it frequently damages young vines to such an extent that they die. It is an insect enemy of the vine that must be eradicated."

There is nothing said about the life history in this account, except that it attacks the vine in the same way as the flea-beetle. It is also given the common name of "Imported Grape Flea-beetle," and we therefore infer that he knew nothing of its attacking the roots. Neither is there anything in the literature of the State which has appeared since that would indicate that it is a root feeder.

Its economic status as given by Cooke was based entirely on the damage done to the leaves. Important as that is, it is really of much less consequence than the attack on the roots, as is now known to be the case. Accounts of injury by this beetle have appeared from time to time since in the press of the State. Alexander Craw[2] then State quarantine officer, gave a short account of the beetle in 1897. He described its attack on the leaves, and figured a leaf showing the characteristic work of the beetle, but was apparently unaware of its underground habits.

Riley and Howard[3] in 1891 stated that "In Europe *Adoxus vitis* is injurious to the grape, the larvæ feeding on the roots and the beetle destroying the leaves, whereas in America it is only known to attack a wild plant (*Epilobium*). Mr. E. Dupont has recently investigated the subject of oviposition and finds that it occurs only on the foliage, the young larva afterwards entering the ground. The life history of *Adoxus* is thus in conformity with that of an allied species, *Chrysochus auratus* which lives on *Apocynum* and *rosoemifolium.* We have found the eggs on the leaves and the larvæ underground feeding on the roots. The nearest North American allies of *Adoxus*, viz., the species of Fidia, also infest the grapevine, but their life histories have

[1] Injurious Insects of the Orchard and Vineyard, 1883.

[2] Destructive Insects, 1897.

[3] Insect Life, vol. III, p. 349.

never been investigated." The first actual observation on the root-feeding habits on the grape in this country, so far as we know, was made by Mr. O. Butler of this station, who found it on the roots of vines near Lodi in 1905.

Its Name.—A beetle was described in 1602 by Aldrovandi,[1] which seems to answer the description of this species; but it was placed in the wrong group by this author, and it was also before the adoption of the binomial system of nomenclature. It has been described under two or three different generic names since, but the one now adopted is *Adoxus,* given by Kirby in 1837.

Linnaeus in 1741 described a beetle, to which he gave the specific name *obscurus.* This is now known as *Adoxus obscurus,* and is the name that has been applied to the black form of the beetle occurring in California and elsewhere in the United States. Mayet[2] states that *obscurus* Linn. is somewhat larger than *vitis,* entirely black, and found on a plant (*Epilobium*) of the marshy prairies, sometimes upon "trifli" clover, but never on the vine. Dr. Horn[3] states that the only known species of the genus inhabits Europe and the northern part of our own continent, and that it varies in a similar manner in both regions.

In California it is certain that both the black and brown forms are the same species. Wherever the beetle was seen during the past two years the two forms occurred in about equal numbers, and were found interbreeding in all combinations. A large number of specimens of *A. vitis* were kindly sent to us by Professor Valery Mayet of Montpellier, France, and they appeared to be identical with the brown form occurring here. He also sent us two specimens of *A. obscurus,* saying that these were very rare and never found on the vine, as noted above. They were slightly larger than the black form occurring on the vine here.

On account of the great difference in food plants it would appear that the *obscurus* of France is a distinct species from that of *vitis;* but an inquiry into the geographical distribution of the two forms seems to indicate that it is simply a case of a dichromatic species, with one or the other of the two forms predominating in the different regions, with the exception of the California vineyards, where both forms occur in about equal numbers.

On account of priority the correct specific name should be *obscurus* Linn. representing the black form, while *vitis* F. should be applied to the bicolored variety.

In France this insect goes by the common name of *Le Gribouri* or *Ecrivain,* the scrawler or writer; but since these names are hardly

[1] Des Insectes, 1602.

[2] Insectes de la Vigne, p. 322, 1890.

[3] Amer. Entomol. Soc., vol. 19, p. 196.

applicable in this country and because of the possible confusion with the engraver beetles, it does not seem desirable to adopt either of these as a common name for the insect. Cooke gave it the name of "Imported Grape Flea-beetle"; but since it is not a flea-beetle at all, this name is not warranted. Since the life history and habits of this species are almost identical with those of the Grape Root-worm (*Fidia viticida* Walsh) of the Eastern States, and the fact that it is, thus far at least, a grape pest in this country only in California, we have given it the common name of California Grape Root-worm.

Distribution.—According to Dr. Horn[1] the *obscurus* or black form occurs most abundantly in California and Nevada and one specimen has been noted from Colorado. The *vitis* form extends from New Hampshire westward to the Lake Superior region, Utah, Colorado, and Washington, only a few specimens coming from the last three localities. Dr. Hamilton in his catalogue mentions *Adoxus vitis* as "widely distributed across the northern part of the continent, extending north on Mount Washington, N. H., to the Hudson Bay region, westward to California and south to New Mexico; and southward in the Atlantic States through New York." A. L. Melander, entomologist of the Washington Station, states that there is but a single specimen in their collection taken in the Grand Coulée in 1892. Professor Cordley of the Oregon Station writes that he has no record of its occurring in that state on the grape, nor has Professor Aldrich any record of its occurrence in Idaho.

Through the kindness of A. L. Quaintance of the Bureau of Entomology, Washington, we are able to give the localities of *obscurus* and *vitis* occurring in the National Museum Collection, as follows: Mount Adams and Mount Washington, N. H.; Marquette and Port Huron, Mich.; numerous specimens from New York and New Jersey; Isle Royal and Michipicoten Bay, Lake Superior; Colorado Springs, Veta Pass, Elk Park, and Garland, Colorado; Bear Paw Mountain, Mont.; Park City and Alta, Utah; Kaslo and Bear Lake, B. C.; Easton, Washington; Portland, Oregon; Placer, Alameda, Los Angeles, and Sonoma, California; and Bulah, New Mexico.

We are indebted to Dr. E. C. Van Dyke, of the California Academy of Sciences, for some interesting facts on the distribution of *Adoxus,* from whom we quote as follows: "The various species of its native food plant, *Epilobium,* is widely distributed over the northern parts of Europe, Asia and North America. On the Pacific Slope the beetle is found in all of the lowlands of western Washington and the northern half of western Oregon and extends south along the Cascades (here up to near the timber line, some specimens being taken at an elevation of 10,000 feet on the snow fields of Mount Rainier); along the Sierras to

[1] Trans. Amer. Entomol. Soc., XIX, p. 198, 1892.

at least as far south as Tulare County, California. This region, including also the Eastern States, with the exception of the Sierras in California, is occupied by the bicolored variety *vitis* F. The melanotic form or true *obscurus* L. has been found besides in California, in Colorado, and one specimen, among many thousands of the variety *vitis* F., at Port Angeles, Washington.

"The insect is found throughout Siberia, where in the Amoor region and around Lake Baikal, the true *obscurus* L.—according to the catalogue of L. Von Heyden, which clearly differentiates the two forms—is the dominant one, and perhaps as much a race there as it is here. In west Siberia the variety *vitis* F. seems to be the predominant one. This peculiarity of distribution is in keeping with that of many of the other species of beetles that are common to both continents, the eastern specimens related to the more western of those of the old world, while ours are more closely related to those of the highlands of southeastern Siberia, etc., the so-called Japano-Manchurian region."

It appears then that the *obscurus* form living upon its native food plant in the Sierra Nevada mountains has transferred itself to the vineyards, but here instead of *obscurus* occurring exclusively, both *obscurus* and *vitis* occur in about equal numbers. The points at which the beetles were reported as injurious this year from Merced to Marysville, parallel with the Sierras, points strongly to the fact that it has come down from the mountains and established itself in the vineyards of the valley. The beetles also occur in the Sonoma Valley, and this may be accounted for by the fact that its native food plant is also found here. According to Jepson,[1] the fire weed (*Epilobium spicatum*) has been collected in western and middle California only in Sonoma County, near Guerneville. The distribution of this insect, with its varying color forms in the different regions and its apparent transfer to cultivated plants, present an interesting biological problem.

As an economic species it is widely distributed in Europe, occurring particularly in the vineyard sections of France, Italy, and Algeria. Here in the United States it seems to have gained its strongest foothold in California. According to Cooke it was reported from six of the principal grape sections of the State as far back as 1882. Within the last two or three years it has been most abundant in the Sacramento and San Joaquin valleys, and in the coast region near Sebastopol and Healdsburg.

Related Species.—In the Eastern States, particularly in the grape growing sections of Ohio and the Chautauqua belt of New York, there is a similar insect called the grape root-worm (*Fidia viticida* Walsh) that does very serious injury to the vineyards. This insect has been

[1] Flora of Western and Middle California, p. 329.

known to occur in New York since 1866, and has been a pest on the vines there since about 1893.

This insect in all essential respects, so far as habits go, is similar to the one treated of in this bulletin. It is also closely related entomologically, both being members of the same group (*Emolpini*). The common *Diabrotica*, the flea-beetles, the asparagus beetle, and numerous other leaf eating beetles belong to this same family.

Economic Importance.—While the insect has occurred on vines in the State for the last thirty years it seems not to have spread so rapidly as might have been expected, judging from the experience with the same insect in Europe and its related species in the Eastern States. It is difficult to explain just what may account for this.

Since the greater part of the insect's life is spent in the ground, it is in this stage that conditions would be most likely to influence its progress. Such conditions might be found in the kind of soil, the cultivation of the soil, the variety of vines and the great depth of the root systems in some of our drier sections. Again, the true importance of the insect's work has never been appreciated in the State hitherto, since it has been known as a leaf feeder entirely. Vines, therefore, may have shown a general unthriftiness due to its attacks, but because the root infesting habits of the larvæ were unknown the trouble may have been assigned to other causes.

However, during the present season in the neighborhood of Lodi, we have good evidence of what injury the insect may bring about. In the particular vineyard where our studies were made, it had been noticed that something was wrong with the vines, but just what it was had not been determined. During the past winter two or three acres of the vines which were worst affected were dug up. The piece adjoining where these vines were uprooted was badly infested during the past spring with a beetle with which the owner (who came into possession of the property a year ago) was unfamiliar. The matter was reported to us and upon investigations it was found to be the root beetle.

The beetles were very abundant over a narrow strip in the center of the vineyard and had already done considerable injury to the leaves and other growing parts of the vines. The men who pruned the vineyard in the winter noticed that this strip of vines had not made the growth that was made by the vines on either side. Fortunately the old stumps and roots which had been dug up had been saved for fuel, and upon examination were found to be badly gnawed by this insect. Some of the vines in the strip where the beetles were abundant this year made practically no growth until late in the season. The beetles were nearly all killed on this area this year, and hence the vines became free from the larvæ and started their growth very late. On another vineyard

near Lodi these beetles have been very numerous for two or three years, and the owner estimated that his crop had been reduced from one third to one half. These two instances are comparable with what has occurred over a considerable area in the Eastern States on account of the presence of the other species there.

Our species has been observed in several vineyards, and doing considerable damage in 1908 where they were not seen at all in 1907. This may be partly accounted for through the excessive rain in the spring of 1907 causing their temporary disappearance, but there is no doubt that the insect is becoming more widely distributed. The station has also received more inquiries about the insect than usual during the season just passed.

The attacks of this beetle have been credited with being the cause of the sunburn of the Tokay grape. The theory of those who support this view is that the gnawing of the beetles on the stalks, pedicels and berries "poisons the sap" or injures the bunch mechanically, and thus induces the drying and shriveling of the berries.

The experiments and observations of Messrs. O. Butler and B. J. Wingfield, at Florin in 1905, indicate that the above-ground attacks of the beetle have little or nothing to do with causing sunburn unless, of course, there is more or less actual defoliation. Besides exposure, sunburn seems to be due to several causes, tending to diminish the vigor of the vine, and probably the underground attacks of the beetle larvæ are among the most serious of these weakening causes.

The Soil It Infests.—The typical soil in the Tokay grape section about Lodi is a sandy loam. It is in such soil that the vineyards mentioned above are located. In another vineyard, however, near Stockton, beetles were present in considerable numbers in the black adobe soil characteristic of that region. About Florin, where the soil is clayey, the insect is also troublesome.

Dr. Felt[1] in speaking of the eastern root-worm's preference for soil says: "The depredations of this pest are much worse and usually first apparent in light, sandy or poor soils, and in particular on gravelly knolls. The insects seem to thrive under such conditions and a deficient growth should lead to immediate investigation. Vines on rich clay soils in our experience sustain comparatively little injury from this pest, and this appears to be the case in Ohio."

Preference for Varieties.—With a view to determining whether or not some varieties are resistant to the attacks of the eastern species, the Cornell Experiment Station secured roots of several types of American vines, and after grafting them on to the standard varieties grown there, distributed them in the infested districts. The work is still in the experimental stage, but it may be promising as a line of possible

[1] New York State Museum Bulletin 59.

control for such a root infesting insect. In the same bulletin it is stated that some large vines of a "native type" growing along a fence within a few feet of a badly infested Concord vineyard suffered no injury, not even the leaves being eaten by the beetles.

Our own observations on the matter of resistant varieties for the root-worm in California have not been extensive enough to warrant drawing any conclusions. The infested vineyards at Lodi are of the Tokay and Zinfandel varieties, but since these are the principal grapes grown here, it proves nothing. In other sections many different varieties of vines are subject to attacks by this insect.

APPEARANCE AND DESCRIPTION OF THE STAGES.

The Egg.—The eggs of this beetle are small yellowish white objects

FIG. 1. A cluster of eggs as they are found naturally on the bark (enlarged).

FIG. 2. A single egg highly magnified.

which may be found in clusters (Fig. 1) under the old bark of the vine. An individual egg (Fig. 2) is about one twenty-fifth of an inch long and somewhat cylindrical in shape, being about one third as broad as long.

The Larva.—The full grown larvæ vary considerably in size, but the larger number will measure a little more than a quarter of an inch, as they are found naturally in a slightly curved position. When they are straightened out they measure seven twentieths to eight twentieths of an inch. They are white in color, excepting the head, which is yellowish brown, with the mouth parts dark brown or black. The arrangement of hairs is as shown in figure 3. The spiracles are indicated by a yellow-

ish spot or ring and are easily visible. The proximal joint of the labial palpus is as long as the other four. The antennæ are short and inconspicuous, consisting of three joints and ending in a couple of peg-like processes and two small spines. The legs are covered with hairs or setæ similar to those on the body. The claws are long, slightly curved, and dark brown in color.

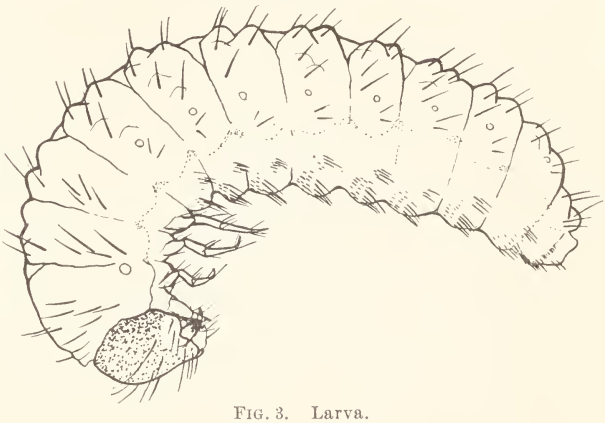

Fig. 3. Larva.

The Pupa. — The pupa (Figs. 4 and 5) is about one fourth of an inch long and about the same length across the extended wing pads. The color is pure white, the hairs or spines alone being colored brown. On the head near the prothorax, extending transversely, is a row of four spines, and behind this row are four spines, slightly smaller, arranged in the form of a quadrangle. On the dorsal side of the abdomen are transverse rows of delicate hairs. The anterior and hind femora are armed with a stout spine. On the hind femora there are also two stout bristles. The anal hooks are very stout and broad at the base, ending in a sharp spine, curved upward and tipped with black. Just anterior to the anal hooks on the dorsal side is a row of four short blunt spine-like tubercles, each ending in a bristle. On the next anterior segment is a row or six spines. These are longer and stouter than those on the other segment, but end in a similar sharp bristle. There are two pairs arranged on either side

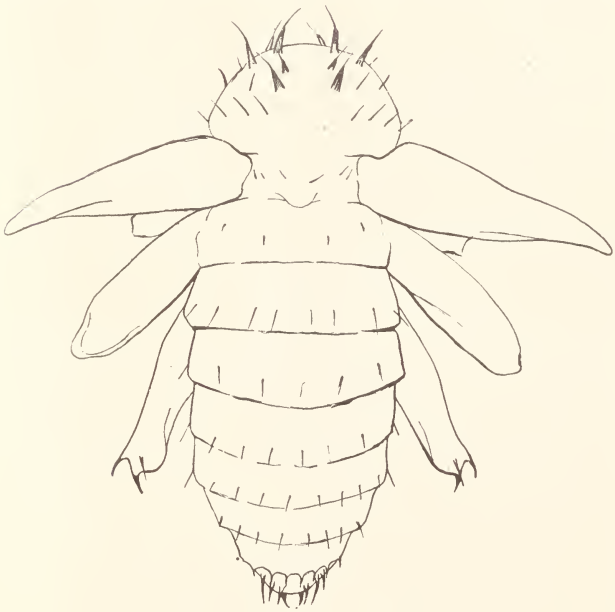

Fig. 4. Pupa. Dorsal view.

of the dorsal line, and below these laterally is a similar single spine. There are also hairs or bristles extending farther laterally.

FIG. 5. Pupa. Ventral view.

The Beetle.—There are two forms of the adult beetle occurring in the State, one being black in color and the other mostly brown. There is considerable difference in the size of different specimens, and particularly in the sexes—the males being much smaller. On an average they will measure about one fifth of an inch in length.

The black form (*Adoxus obscurus* Linn.) is almost wholly black in color. The antennæ, tibia and tarsi, however, in some specimens merge into dark brown. The entire body, as well as the appendages, are covered with a pubescence of short gray hairs.

FIG. 6. Adult of the grape root-worm.

The brown form (*Adoxus vitis* Fab.) has the elytra, tibia and basal half of the antennæ brown, while the remaining parts are black. It is covered with a gray pubescence as is the other form. The head in both is capable of being well retracted into the prothorax. Both forms of the beetle are about equally distributed, and interbred indiscriminately.

LIFE HISTORY AND HABITS.

The Egg.—The eggs of this beetle are laid usually in crevices beneath the inner layers of bark on the old wood. They are not confined to last year's wood, as seems to be the case with its eastern ally, but are laid anywhere on the stump of the vine above four or five inches from the ground. With the California system of pruning, there is of course little of last year's wood left on the vine, and the bark on this is too smooth to offer the most suitable situations for egg laying. Indeed, during the past season we found no eggs on last year's wood, but all on the older part of the stump, which was covered with two or three layers of old bark. In some cases, where the bark was in close contact with the wood, it was hard to explain how the beetle got beneath the two or three layers to deposit its eggs. In nearly every case they were certainly well protected from most enemies and out of reach of any spray.

The eggs are laid in clusters of from four or five to twenty-five or thirty; usually where the smaller numbers were found the crevice in which they were deposited would not furnish room for a larger number. Where there was plenty of space the number ranged from a dozen to thirty. The most common numbers counted in the many clusters examined ranged from ten to twenty.

The eggs in the cluster may be irregularly arranged or somewhat in the form of a concentric ring, the particular arrangement depending probably upon the space in which they are deposited. Where there was plenty of room the eggs were sometimes well scattered, extending over a diameter of a quarter of an inch or more. In other cases a pretty well defined concentric arrangement was found. Occasionally, a small crevice would be found with but two or three eggs.

Number.—The largest number we succeeded in getting a single female to lay in our breeding cages was seventy-nine. These were laid at three different intervals, extending over a period of about one month. Others laid but a single cluster of from fourteen to twenty and then died. The same insect in France, according to Mayet,[1] lays in the neighborhood of thirty eggs either singly or in patches on the under side of the leaves. This number is probably simply an approximation. The fact, if it is a common occurrence, that they are laid on the under side of the leaves, is the most striking difference between the habits in California and in France. We have had some eggs laid on leaves in our breeding cages when there was nothing else for them to oviposit on, but we never found any indication of this habit in the field.

From our breeding cage experiments and field observations we are

[1] Insectes de la Vigne, p. 308.

inclined to think that few, if any, deposit more than three or possibly four clusters, making a total of not to exceed one hundred, or possibly, one hundred and twenty eggs. From fifty to seventy-five will be nearer the average. The majority of the beetles in our cages laid but a single cluster of twenty or twenty-five, but those were under slightly unnatural conditions where there was not a constant supply of fresh food. A number of females were dissected to determine the number of eggs in the ovaries, and these varied from sixteen to twenty-four well developed eggs.

The eggs of a cluster are very slightly glued together with a sticky material. By careful handling it is possible sometimes to take these off en masse, but the majority of clusters will fall apart upon the slightest handling. The eggs of the eastern species are said to be covered with a gummy material which holds the entire mass securely together, but with this species we failed to find any that would withstand any very rough handling or which could be blown off the vine in clusters by the wind.

FIG. 7. Larva of the California grape root-worm, as it appears in the soil (enlarged).

Time Required to Hatch.—In our breeding cages the shortest time required to hatch was eight days, and the longest period twelve days. This was under conditions which varied but little from that of the vineyard, the temperature being lower, if in any way different, especially in the forenoon, since the laboratory had a west exposure away from the morning sun. A large number of eggs were thus timed for the incubation period and they all came within the limits stated above. This, of course, may vary in warmer or colder weather, but from ten to twelve days may be taken as the average hatching period. The eggs of the same cluster were all observed to hatch within one day.

The Larva.—The young larva upon hatching from the egg makes its way to the ground almost immediately. It may crawl to the ground, as we infer from finding them pretty well scattered down the trunk of the vine, or they may possibly in many cases simply drop to the ground, though this was not actually observed. This seems to be a common habit with the eastern species, but here in California with the short-pruned vines, and consequent nearness to the ground, we believe that most of the larvæ crawl down the trunk. Young larvæ kept under observation in a test tube filled with compacted soil, wan-

dered about looking for a suitable place for entering the earth three or four hours before they actually disappeared. By the following morning they had gone about halfway down the tube, or three inches,

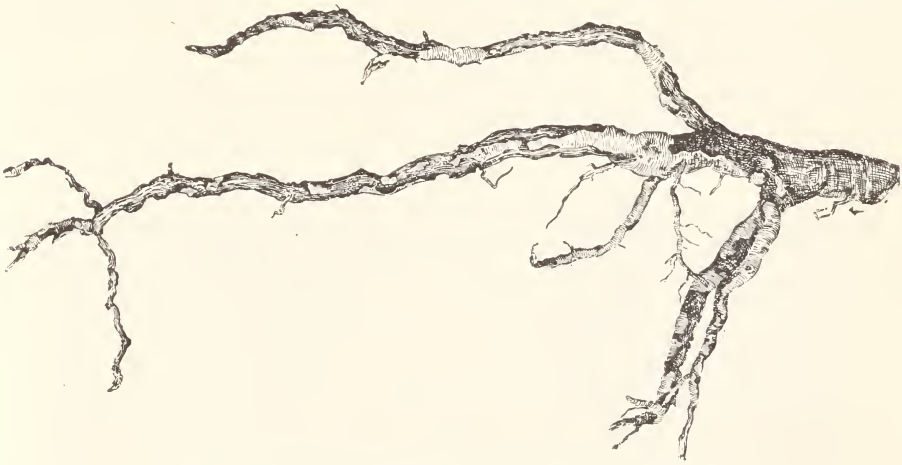

FIG. 8. Root of a vine with bark eaten off by root-worm.

and before the end of the same day they had burrowed through the six inches of soil in the tube.

As soon as the larvæ reach the roots of the vine they begin feeding, and it is generally the smaller rootlets that are first attacked,

FIG. 9. Stem leaf and fruit eaten by root beetle.

although we have found young larvæ around roots of considerable size. These smaller roots may be eaten off entirely. The larger roots are injured by the larvæ gouging out long strips of the bark, which sometimes take almost any direction, but on the roots of medium size these

strips are usually eaten out in a direction parallel with the axis of the root, or in a spiral direction. The "frass" or eaten bark is left in their paths and is characteristic of their injury. The furrows made are from one tenth to one fifth of an inch wide, and in cases of severe injury all the bark may be eaten away from the roots.

This feeding is continued from the time they hatch in the spring until the vine becomes dormant in the fall. By September 1st some of the larvæ were found nearly full grown, while others were not more

FIG. 10. Grape leaf showing characteristic work of the beetle.

than half grown. In the case of the latter, their growth is completed by feeding during the following spring, which accounts for some of the larvæ being found as late as the last of May. The first observed appearance of the young larvæ in the Lodi section in 1907 was on May 30th, this being about a month after the first appearance of the beetles.

The larvæ were found as far down as two and a half feet, and no doubt go farther than this, since in some of the vines there were no roots to speak of nearer than a couple of feet from the surface. The larvæ were found within a radius of fifteen inches from the main central root, and no doubt the majority occur within a radius of a couple of

feet. They apparently remain dormant during the winter season, changing to pupæ the following spring. Some full grown larvæ of the preceding year were found about the roots as late as May 29th during 1907.

The Pupa.—The full grown larva which has wintered over in the ground changes to the pupa in the early spring. The larvæ upon reaching maturity ascend toward the surface for pupation. The pupæ taken this past season were found at a depth varying from four to eight inches below the surface. The depth depends somewhat upon the amount of moisture near the surface. Those found nearer the surface were taken from where there was considerable moisture to within two or three inches from the surface. The pupæ, being covered with a delicate white skin, require a fairly moist soil to prevent them from drying or shriveling up. We met with this difficulty of drying with some of the pupæ taken to the laboratory.

Fig. 11. Tip of a shoot, with the leaves, stem, petioles and pedicels attacked by the root beetle.

About two weeks is required for the development of the insect in the pupa stage. The first adult beetles seen in 1907 and 1908 were discovered about May 1st, so that pupation must have begun about the middle of April. The insect may, however, remain in the pupa stage for a month or more.

The pupa simply rests in a little cell hollowed out by the larva, and any disturbance of the earth is very likely to break this cell and expose the pupa, which on account of its delicate structure will usually succumb to such treatment.

The Beetle.—The adult beetle, into which the pupa in its cell in the ground transforms, emerges from the ground and begins to attack the growing parts of the vine above ground. For the greater part of the season the insect has been a root feeder, but having completed its early stages underground, it comes to the surface to feed for a brief time, to lay its eggs, and then dies. The beetle as it comes from the ground is somewhat lighter in color, but upon exposure to sun and light its chitinous covering soon becomes darker in color and more rigid in texture.

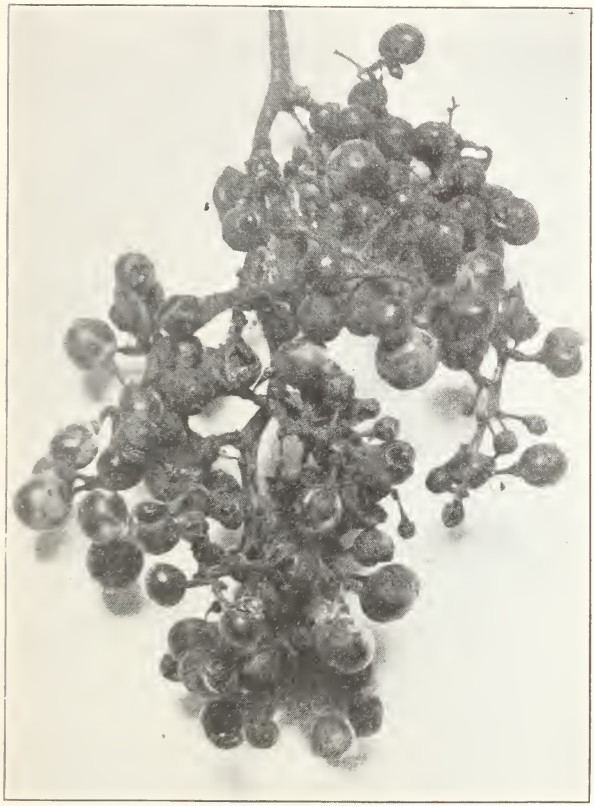

FIG. 12. A cluster of grapes badly gnawed by the root beetle.

The time of appearance of the first beetles during the years 1907 and 1908 at Lodi was May 1st. They may continue to emerge until June 1st and possibly later, although the greater number of the beetles came out in 1907 and 1908 during the first half of May. It has been stated that a few larvæ and pupæ were taken on May 29th, which would indicate that a few belated beetles may not appear before the middle of June. The beetles were most numerous on the vines this season about the middle of May. In the latter part of May they begin to disappear and by the last of June are practically all gone.

The beetles soon begin their work on the vine by feeding upon the leaves. They are nearly always found on the upper surface. In feeding they eat out chain-like strips from the leaves (Fig. 10), these slits being about one twentieth of an inch wide and from a quarter to three quarters of an inch long. Sometimes the framework of the tissues is left, making a skeletonized effect, though often the entire substance is

eaten away. This gives the leaf a lace-like effect, the parts left in cases of bad injury being held together by mere threads.

The beetle also gouges out strips of the bark of the tender shoots in the same manner as it works on the leaves (Fig. 11). Sometimes the shoot is thus gouged out all the way around and turns brown in color. This loss of bark or covering interferes considerably with the conveyance of nourishment to the fruit and growing tip. The petioles of the leaf are similarly attacked, as are also the pedicels of the berry; and the pedicels being of a small size, a few gougings around them will cause the berry to dry up.

The berry itself does not escape the attacks of this beetle, and in July berries may be seen that are cracked

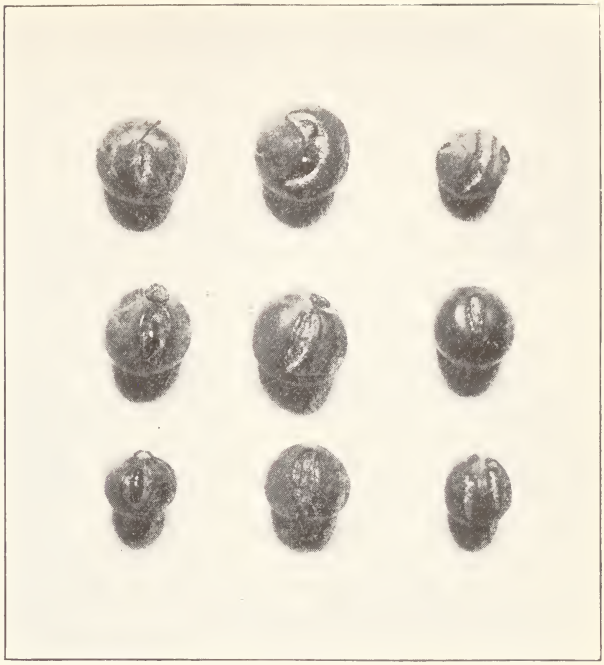

FIG. 13. The work of the beetle on the berries.

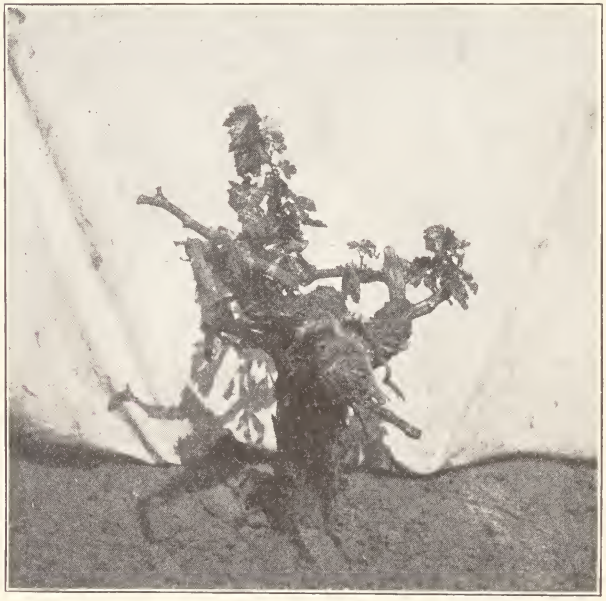

FIG. 14. A vine stunted in growth through injury to the roots by the California grape root-worm. Photographed June 6, 1907.

open or gouged out on one side (Figs. 12, 13), and the growth interfered with as a result of an attack of these beetles in May or June. The beetles may continue to feed for a month or more. After feeding a couple of weeks egg laying begins, and this takes place at intervals of a week or two, when the clusters of eggs are deposited as already indicated.

The beetles are very easily jarred from the vine upon the slightest disturbance, and fall to the ground "playing 'possum" and remain quiet for a short time, but soon become active again when left undisturbed. This habit of readily dropping to the ground offers a means of controlling the insect in this stage. The beetles fly around but little, and will usually be found in the immediate vicinity in which they emerged. The vineyards which were under observation showed that the great bulk of the beetles were confined to a comparatively small area, and reports from the owners indicated that they had been present in these spots for several years.

In the case of some vineyards, according to statements made by the owners, these beetles have been present for a good many years. In such cases as these there seems to have been some factor in keeping them from becoming excessive and destroying the vines. In one vineyard near Lodi, where the beetles are said to have been present for many years, they have become especially abundant only during the last year or two. During this period they have also spread more rapidly, and since it has become known that they feed upon the roots as well as the leaves the growers have begun to realize their importance, and remedial measures will be undertaken against the insects.

CONTROL MEASURES.

Natural.—Probably the most important factor in the way of climatic control of this insect would be unusual rainfall during the winter season. During the winter of 1907, which was a very exceptional one, large areas were covered with water which hitherto were unknown to have been flooded. Where this exceptional amount of moisture prevailed and vineyards were covered for a couple of weeks, there were very few beetles during the following season. Except in one or two cases, however, we were not aware of the fact that beetles had occurred in those situations in previous years. But they were, nevertheless, present again in 1908.

Aside from excessive moisture in the soil, there is little in the way of climatic control that will aid in the fight against the insect, unless it would be in some condition that would be conducive to the development of a fungus affecting the adult beetle. In our interior California weather, however, of May and June there is little hope of anything

very effective appearing as dependent primarily upon moist weather. The fact that the eggs of this beetle are very securely hidden away beneath one or more layers of bark affords little opportunity for them to be attacked in any large manner by parasitic or predatory insects. The young larva is for a brief period (from the time of hatching until it enters the ground) more or less exposed to the attacks of enemies, but the interval is generally too short to allow of very great destruction. Once in the ground—where it remains for the greater part of the year—it is pretty safe from most enemies. About the only thing likely to attack the larva here would be the predaceous ground beetles. None of these were actually observed attacking them during the past two years. The larva is usually so deep in the ground as to be out of reach of most natural enemies.

The pupa comes nearer to the surface and is hence more liable to attack. It is probably in this stage that the greatest mortality occurs, both from enemies and from cultivation of the soil and other operations by man. In the adult or beetle stage, the insect is directly exposed and is likely to be attacked by a large number of enemies, including insects and birds.

ARTIFICIAL CONTROL.

Of the Egg.—Since the eggs are secreted under one or more layers of bark, there is little possibility of any spray or wash reaching them. On account of their small size and the difficulty of finding the clusters, hand picking is out of the question. Those who believe in stripping off the old bark and spraying with bluestone during the dormant season, with the primary object of preventing black knot, will, incidentally, inconvenience these beetles by doing away with the more favorable situations for egg laying. This, however, can not be counted upon as very effective in controlling the beetle. The eggs will be deposited in spite of this treatment, and freeing the vines from their loose bark will result simply in rendering the eggs a little more exposed to the attack of enemies.

Of the Larva.—The matter of controlling any underground insect is a difficult problem, and the larva of this beetle is no exception to the general rule. Various remedies and schemes have been tested for accomplishing this work, but the greater number of them have been abandoned. The problem, therefore, is now limited largely to control by resistant stock, cultivation, crop rotation, or other regular farm practices; but, with an insect such as this, that spends a portion of its existence above ground, it is not necessary to control it in the larval stage, since it can be more easily and effectively done in a later stage.

It was suggested by some of the growers that something might be

applied to the ground to prevent the larvæ from entering, but knowing the results of the New York experiments[1] along this line, we gave little encouragement to the idea, and did not repeat the experiments. Kerosene emulsion and crude petroleum were used in New York, but neither proved of any practical value. The trouble with such substances is that they are too readily absorbed by the dry soil and too quickly evaporated. Our California crude oil, which has an asphaltum base (instead of paraffine, as is the case with eastern oils), would not disappear so quickly, but few farmers would want such a substance mixed with their soil.

FIG. 15. At work digging out larvæ of the California grape root-worm two and one half feet beneath the surface.

Of the Pupa.—As heretofore stated, the pupæ are found at a depth of from four to eight inches below the surface. This, together with the fact that any disturbance of the cell in which they are resting will generally prove fatal, offers a chance of doing something in the way of control while in this stage. While some of them are beyond the depth of the plow as ordinarily used about the vine, yet probably the majority will be found within about six inches from the surface. They do not come up to the dry soil to pupate, but remain just below it. If a shallow mulch of two or three inches can be kept immediately around the vines until the insects are ready to pupate, this will conserve the

[1] New York State Museum Bulletin 59, p. 77.

moisture just below the mulch and encourage the larvæ to come nearer the surface to transform to the pupæ. If then, at the proper time, just before the beetles begin to emerge, the soil about the vine is stirred to a depth of about six inches, no doubt a large percentage of them will be destroyed. Another point, and one which makes the problem more difficult, is that the pupæ do not all appear at once, but may be found for a month or more. This may make it necessary to go over the ground more than once. However, probably the majority of the beetles emerge at about the same time in the early part of the season, and, if measures are taken against the pupæ just preceding the emergence, large numbers of them will be destroyed. If more than one cultivation

Fig. 16. Vines enclosed with mosquito netting to determine if beetles will emerge through uncultivated soil.

is undertaken they should be done at intervals not to exceed two weeks, since the pupæ will complete their development within this period.

This matter of deep cultivation for two or three feet around the vine, while not expected to completely control the insect, will, nevertheless, aid in its control. It is, of course, of no use unless done at the proper time—when the insect is in the pupal stage. The proper time for such cultivation during the past two years at Lodi would have been during the last of April, but this may vary with the season and locality.

It is possible that in some soils the destruction of the beetles before they emerge from the ground may be accomplished in another way. In making some experiments at Florin, in 1905, for the determination of the causes of the sunburn of Tokay grapes, Mr. B. J. Wingfield

found that the beetles were unable to force their way out of the ground when it was covered with a hard, uncultivated crust, such as is left after rain on clayey soils. Each of six vines was covered on May 4th with a cage of mosquito netting. In three of these cases the netting was tied tightly around the lower part of the stem, as shown in figure 16, in order to prevent the possibility of any beetles getting on to the above-ground portion of the vine. In the other three cases the netting was brought down to the ground, enclosing about three square feet of soil surface inside the cage, as also shown in figure 16. This enclosed surface remained uncultivated until about the middle of July, when the cages were removed.

FIG. 17. A single vine as shown in figure 16.

No beetles were found at any time on any of the six enclosed vines, and no signs of their attacks on leaves, fruit or other above-ground portions. This is easily explained in the case of the vines which were completely shielded from attack by tying the netting around the stump; but in the case of the other vines which were exposed to any beetles which might emerge from the soil within eighteen inches from the stump, the only explanation seems to be that the beetles were unable to force their way through the compacted surface crust. That the pupæ and beetles were abundant in the ground was shown by the fact that all the uncovered vines next to those which were covered were badly infested by the beetles and showed abundant evidences of their attack on all parts.

The effectiveness of a method based on this experiment would depend largely on the type of soil. Only a soil that will form a hard, compact surface layer could be utilized according to this plan.

We do not know how it would appeal to the growers to leave three or four feet about the vine uncultivated until about the middle of May or possibly later, as would be necessary in this case; but if the beetles were present in large numbers and this controlled them, it would pay amply. Again, showers of rain that are apt to come as late as the middle of May would soften the soil and militate against the method.

Spraying.—The adult or beetle eats away portions of the leaf or gouges out strips of the surface of the shoots and other growing parts, so that a poison applied to the vine will be consumed by it in this operation. The most serious drawback to poisoning is the fact that beetles are pretty resistant to poisons, and considerable amounts must be consumed before the insects are killed. However, if a strong arsenical spray is thoroughly applied at the beginning of the attack it will prove to be fairly successful.

In the experiments this season the beetles were killed in from two to three days on leaves thoroughly sprayed with lead arsenate in the ratio of five pounds to fifty gallons of water. One pound of paris green to seventy-five gallons of water also gave good results. In the case of paris green a few vines should be used as a test to determine the maximum amount that is safe for the foliage, since there is danger of burning if used too strong.

It is not a very difficult matter to spray the short-pruned California vine during the last of April or the first of May, and thorough work can be done at this time. The spray should be applied mostly from above, since it is on the upper surface of the leaves and shoots that most of the feeding is done.

Jarring.—Since the beetle is very readily jarred from the vine, this offers one of the most satisfactory means of controlling the insect. Generally it is only those that are in a cup-shaped leaf, or in a grape cluster, or in some part of the old wood, that will not be disturbed by a reasonable jarring.

This method has the advantage of killing the beetles directly, before egg laying is commenced, which may not always be done by means of the poison spray. The worst objection to the method is that the beetles may keep emerging from the ground for three or four weeks, making more than one treatment necessary. Fortunately, however, these attacks are generally confined to a limited portion of the vineyard, so that the problem is not so difficult as it would be were it necessary to go over the entire area.

The sort of apparatus which was used successfully on a badly infested vineyard near Lodi this year was the vine-hopper cage shown in figure 18. This device was constructed for capturing the vine hopper, and when a nearby vineyard became infested with the beetles it was used against them.

This cage consists of an ordinary mosquito netting tacked over a square framework of laths or some other light material. The essential part of it so far as the beetles are concerned is the tray at the bottom. This is made of a sheet of galvanized iron turned up about an inch at the edges. The crude oil which is placed in this tray is fatal to all insects falling into it.

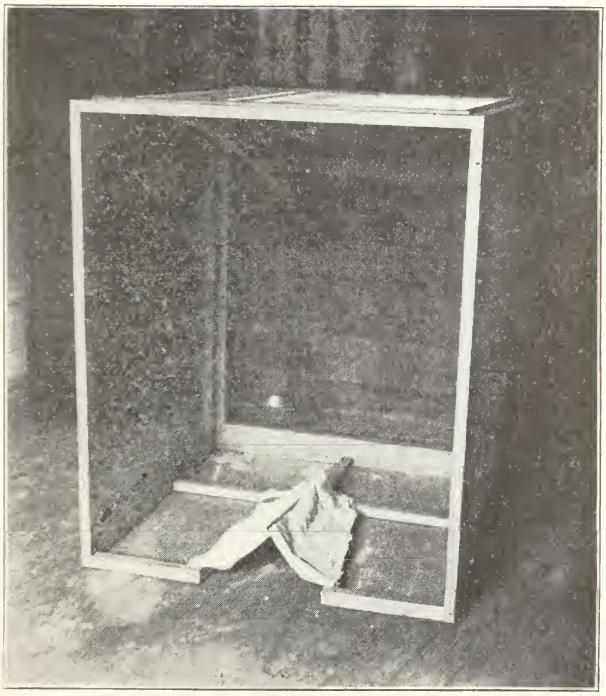

FIG. 18. A cage used to capture the beetles on the vine.

The V-shaped opening in the tray permits the cage to be pushed on to the vine, which is bumped at the same time and the beetles jarred off. A padding of leather is tacked on the base of the opening in front of the vine. The opening may be closed by tacking two strips of canvas, one on each side, so as to meet in the center. These strips are supported by transverse pieces of three-quarter inch rubber tubing, which are sewed on to the canvas beneath. This rubber tubing supports the canvas over the opening, and when the cages are placed in position it gives way for the base of the vine, but immediately springs back again through the flexibility of the rubber. Steel strips will answer the same purpose, but the rubber is described because it is cheaper and more easily obtained.

This cage has the advantage of catching the vine hopper, which is likely to be present, with the same operation. For the beetle alone, simply the tray at the bottom may be used, or the sides extended up

and slightly outward with wire netting or canvas, to get those that may be on the outer parts of the vine. Handles may be attached to this, so that it can be manipulated without stooping. Such a cage can go over four or five acres a day, and there is little outlay save the time of the men doing the work. Since the beetles, if taken in time, are distributed over a comparatively small portion of the vineyard, it means but a day's work or two. This, then, can be repeated three or four times, if necessary, without much expense, and the vines saved from any further ravages of the pest.

SUMMARY.

This insect has been a destructive enemy of the vine in Europe for many years, and for several years past it has been doing considerable damage to the grape in California. A related native species is an important pest of the vines in the East.

It attacks both the roots and the growing parts of the vine above ground. From June to May the insect is in its larval and pupal stages underground. During May and June it works on the parts of the vine above ground as a beetle.

Many of the pupæ may be destroyed by deep cultivation for a radius of two or three feet about the base of the vine.

The beetles may be killed by a strong arsenical spray, or by jarring into crude oil, or otherwise captured as they are shaken from the vine.

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